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Protection ratios for 625-line system I television transmissions, impaired by interfering frequency-modulated television signals

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PROTECTION RATIOS FOR 625-LINE SYSTEM I TELEVISION TRANSMISSIONS, IMPAIRED BY INTERFERING FREQUENCY—MODULATED TELEVISION SIGNALS

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(RA-90)

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Summary

Subjective tests have been carried out to find the protection ratio required by a 625-line system I television transmission, when the interfering signal is f.m. television. The effects of deviation, pre-emphasis, and energy-dispersal of the interfering signal are considered, as well as the addition of random white noise.

1. Introduction

Proposals have been made for setting up experimental community reception television services in India and other countires, with transmitters radiating from a geostationary satellite. Frequency modulation (f.m.) will be employed. The nominal carrier frequency may be in the region of 800 MHz, which is within the band used for terrestrial television broadcasting in Europe. Although the details of the proposed system have not yet been finalised, it is important to establish the protection ratio (p.r.)* which must be achieved, to ensure that interference from the satellite transmissions to the existing and future terrestrial services is at an acceptably low level. In particular, the needs of the United Kingdom, as well as other European countries, demand a knowledge of the effect of the interference upon the 625-line PAL system I, which uses vestigial-sideband amplitude-modulation (v.s.b.). Tentative values of the p.r. had been proposed earlier,[1] but these were based on somewhat limited data, so further investigation has been required. This report describes the results of subjective tests, and proposes a suitable p.r. It considers the effect of the deviation, pre-emphasis and an energy-dispersal waveform in the interfering signal. It also deals with the effect on the p.r. of adding random noise to the r.f. signals.

2. Previous work

If the f.m. has a very low deviation, or if the modulating waveform is at a constant level for an appreciable proportion of the time, the p.r. required must tend to the value appropriate for c.w. interference, i.e. about 60 dB for just perceptible impairment.[2] Values of p.r.s have also been established for interference between similar f.m. systems[3] (f.m./f.m.), and the p.r. for an f.m. signal interfering with an a.m. signal (f.m./a.m.) can be roughly estimated by adding the theoretical f.m. noise advantage over v.s.b. a.m. to the value in the f.m./f.m. case;

this assumes that the same advantage applies to f.m. interference. This leads to figures in the region of 50 dB for just perceptible impairment when the f.m. peak-to-peak deviation is 8 MHz.

The results of some subjective tests on f.m./a.m. interference have been reported[4,5] for the 525-line NTSC system. These tests indicated that when the peak-to-peak deviation of the f.m. signal is 16 to 18 MHz, the p.r. is about 49 dB. This figure is, however, believed to correspond to a grade of impairment slightly less than the "just perceptible" which has been assumed above.

3. Acceptable impairment grade

One of the questions associated with establishing the protection ratio required in a given situation is that of defining the meaning of "acceptable". The 6-point impairment scale** is often used to define the grades of impairment, and for many planning purposes in terrestrial broadcasting the acceptable level has been taken as approximately grade 3·5 on this scale, but such a relatively high impairment has been accepted only in situations where the interference is present for a small percentage of the time. In the case of interference from a satellite transmission, the level of the interference is more or less constant, so the permissible impairment to the picture must be less. It is probably reasonable to assume in this case that the acceptable mean grade is 1·5. This may be interpreted as implying that 50% of the viewers would not see the impairment, while it would be just perceptible to the other 50%. This is the criterion which will be adopted in this report, except where it is clear that other grades are appropriate.

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* The protection ratio in this case is the ratio of the amplitude of the wanted a.m. signal at the tips of the synchronising pulses to the constant f.m. signal amplitude.

** 1. Imperceptible
    2. Just perceptible
    3. Definitely perceptible, but not disturbing
    4. Somewhat objectionable
    5. Definitely objectionable
    6. Unusable
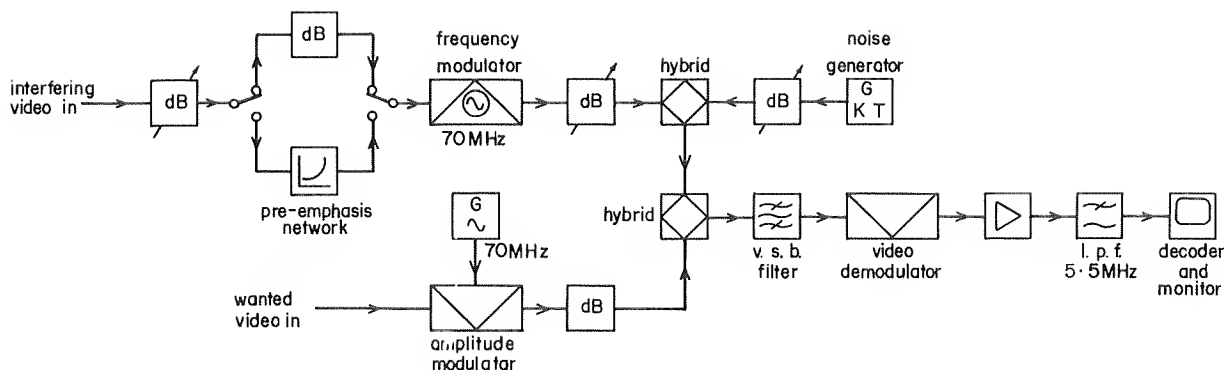(See CCIR Report 405-1, Note 8)

Fig. 1 - Block diagram of experimental arrangement

4. Experimental arrangement

A block diagram of the experimental arrangement is shown in Fig. 1. The wanted vision carrier frequency was 70 MHz. The vestigial sideband filter preceding the wideband detector had the characteristic shown in Fig. 2. Negative modulation was used for the interfering f.m. signal, i.e., white level corresponded to a lower frequency than black level. The f.m. modulator was a.c.-coupled, and a.f.c. maintained the mean frequency at 70 MHz (except for certain tests where the mean frequency was deliberately changed). The peak-to-peak deviation for most of the tests was 8 MHz.
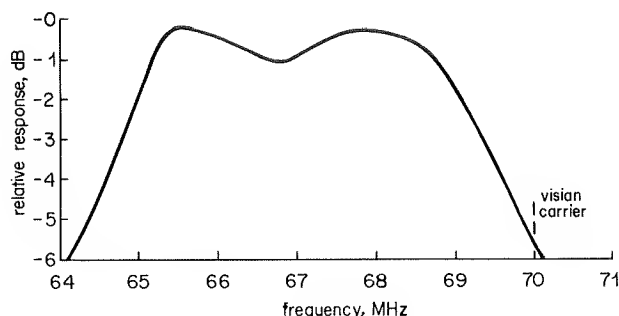

Fig. 2 - Vestigial sideband filter characteristic

The pictures were viewed on a 21″ colour monitor. The viewing distance was five times the picture height. The observers were technical personnel.

The test pictures were stills, obtained from a flying-spot scanner.

5. Slope of curve of impairment versus protection ratio

The first test was intended to establish the relationship between picture impairment and protection ratio, over a fairly wide range. The p.r. was varied in 2 dB steps from 41 dB to 61 dB. The different p.r.s. were presented in a random order. The interfering modulation was a line sawtooth, and the line frequency was not locked to that of the wanted signal. Two still slide pictures were used for the wanted signal. These pictures were the same as those

used in a previous investigation into f.m./f.m. interference.[3] Each condition was assessed by six observers (in two groups of three). The mean values of the assessments are plotted in Fig. 3. For impairments above grade 2, the p.r. decreases by approximately 5 dB per impairment grade.

These tests showed that one picture was somewhat more sensitive to the effects of interference than the other, and in order to reduce the number of variable parameters, it was decided to use only this picture for further tests. This slide is reproduced in Fig. 4. It will be seen that although it contains appreciable areas of constant shade and colour it is by no means an extreme case or an unusual type of transmitted picture.

It was suspected that, although the wanted pictures employed in the tests provided a fairly sensitive check on the impairment, the nature of the interfering signal may have been such as to reduce the impairment below that which may often occur in practice. Firstly, the line frequency differed from that of the wanted signal by several Hertz, and secondly, the f.m. produced by the sawtooth waveform ensured that an interfering pattern of the type due to momentarily near-constant frequency would not arise during the picture period. A second test was therefore carried out, in which the interfering modula-
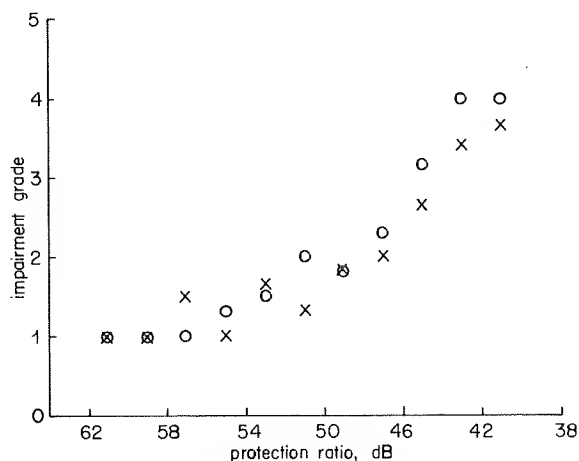

Fig. 3 - Impairment grade vs. protection ratio: sawtooth interference
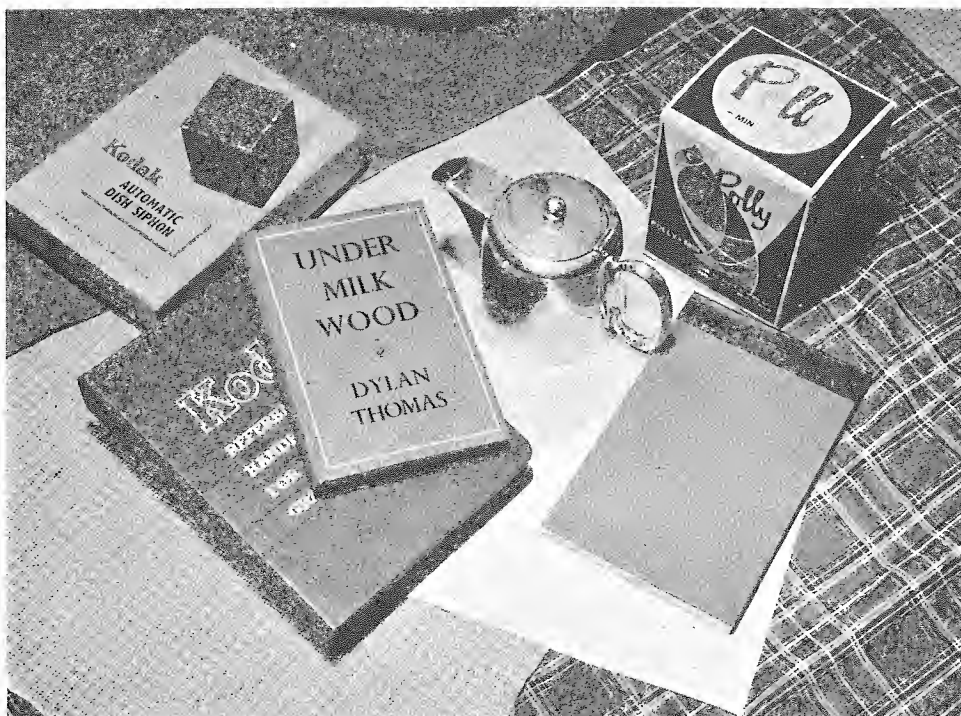
O   Picture 1
X   Picture 2

Fig. 4 - Slide used for wanted picture

tion was colour bars, and the line frequency was very close, but not locked, to that of the wanted modulation (line frequencies differing by about 1 in 10^5). This confirmed that the protection ratio required in this case would be approximately 3 dB greater than that shown in Fig. 3.

6. Effect of pre-emphasis

In the tests described in Section 5, no pre-emphasis was used in the interfering f.m. signal. If pre-emphasis is used, it may be expected that the effect of interference would be somewhat worse, because the deviation of the lower modulation frequencies will be reduced, and a coarse pattern will tend to be produced for a larger proportion of the time. A test was therefore carried out in which a pre-emphasis network was inserted at the video input to the interfering modulator. The pre-emphasis characteristic was in accordance with the CCIR Recommendation 405-1 for the 625-line system.[6] The interfering modulation was colour bars. Six observers were shown various levels of interference, both with and without pre-emphasis. It was found that, on average, the use of pre-emphasis increased the p.r. required for a given impairment by approximately 1·5 dB.

7. Protection ratio tests, with reference conditions

The tests described in Sections 5 and 6 emphasised that parameters such as picture content, the use of pre-emphasis, etc., can significantly affect the p.r. required for a given impairment. For purposes of planning, it is convenient to establish the p.r. for a given set of parameters, which may be called the reference conditions, and then to apply appropriate corrections for particular parameter variations such as, for example, the deviation. The reference

conditions of the interfering signal used here are as follows:

> Colour bar modulation
> 8 MHz nominal peak-to-peak deviation
> Pre-emphasis included (Reference 6)
> No energy-dispersal waveform

Assessments were made by two groups of six observers. The first group was obtained from the personnel used for the tests described previously. The second group consisted of a Working Group, concerned with interference problems. The mean assessments are plotted in Fig. 5. For grade 2 impairment the p.r. is about 54 dB, and for grade 1·5 impairment it is about 56 dB.
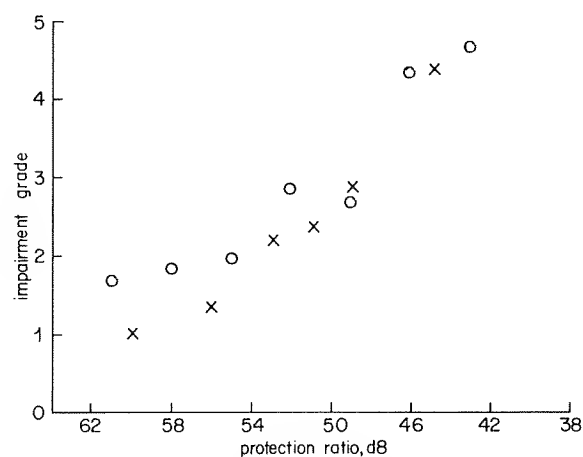

Fig. 5 - Impairment grade vs. protection ratio: reference conditions

> o   Observer group 1
> ×   Observer group 2

8. Effect of deviation of interference

It has already been pointed out that the interfering signal is liable to produce more impairment if its deviation is reduced. The effect of deviation was assessed by one fairly experienced observer. With colour-bar modulation of the interference, and with no pre-emphasis, the p.r. was set to give an impairment of about grade 3 when the peak-to-peak deviation was 8 MHz. The deviation was then reduced to 4 MHz, and the p.r. required for the same impairment increased by 2 to 3 dB. Similarly an increase in the deviation from 7·5 MHz to 15 MHz caused the p.r. to decrease by about 3 dB. Thus, as an approximate empirical rule, it is suggested that, taking the case of 8 MHz peak-to-peak deviation as a reference, the p.r. is reduced by half the number of decibels by which the deviation is increased.

9. Effect of frequency offset

In the case of f.m. interference, it is unlikely that any significant change in the p.r. will be obtained if the nominal carrier frequency is offset by a fraction of the channel width from that of the wanted signal. This is in contrast to the case of a.m. interference, where a suitable choice of small frequency offset can reduce the impairment. In order to check this assumption, some limited tests were carried out, in which the interfering carrier was offset in the direction of the receiver passband, i.e., it was less than 70 MHz. Three observers compared the impairment (about grade 3) in two conditions, firstly with the carriers at nominally zero offset, and secondly with a 2·5 MHz offset. The p.r. at zero offset was 46 dB; at 2·5 MHz offset a number of different p.r.s, varying in 2 dB steps between 40 and 46 dB, was presented. In each case the observers recorded which offset, if any, produced the smaller impairment. When pre-emphasis was used, each observer in each test preferred the 2·5 MHz offset condition, but with no pre-emphasis there was on balance preference for the zero offset condition. Without pre-emphasis when the p.r.s were equal, one of the three observers expressed no preference for either offset.
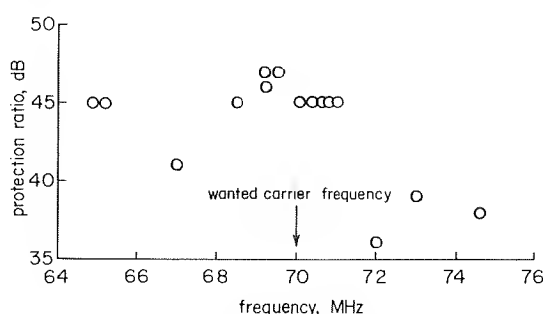

Fig. 6 - Effect of frequency offset on protection ratio

Another test was made by one experienced observer, to assess the effects of a larger number of offsets. The p.r. was first set at 45 dB for nominally zero offset, and no pre-emphasis. Other offsets were then set up, and the p.r. adjusted to achieve the same degree of impairment. The results are shown in Fig. 6. They tend to confirm that the offset does not have a very significant effect upon the p.r.,

provided that the interfering centre frequency is within the receiver passband. The results shown in Fig. 6 may be noted in conjunction with Fig. 2, which shows the shape of the v.s.b. filter in the receiving system.

10. Effect of the addition of random noise

If random noise is present in the picture, the visible pattern produced by co-channel interference may be expected to become somewhat broken up and therefore less visible. In order to assess the significance of this effect, a test was carried out in which three observers decided whether or not the interfering pattern could be seen, for various p.r.s, and with system unweighted signal-to-random-noise ratios of 43 dB, 30 dB and 24 dB. The unweighted s.n.r. of the picture source was in the region of 38 dB. A preliminary assessment was made by one observer to find the range of p.r.s which would be likely to result in just visible interference, with the appropriate s.n.r.

A score of + 1 was given if the interference could be seen, and − 1 if it could not be seen, so that a mean score of 0 may be interpreted as corresponding to an impairment grade of 1·5. In each test, the observers were shown the noisy picture before adding the interference, and each test was repeated three times. The mean scores are plotted in Fig. 7. The scatter of the points makes it difficult to draw firm conclusions, but the results indicate that if visibility of the interference as a separate impairment is the criterion for establishing the p.r., it may be argued that if the unweighted s.n.r. is 30 dB, the p.r. can be reduced by about 6 dB from the value corresponding to a high s.n.r.
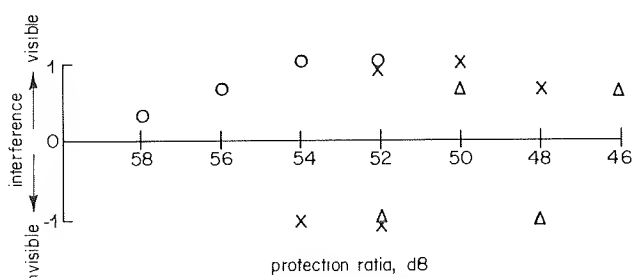

Fig. 7 - Effect of random noise on visibility of interference

system s.n.r. (unweighted), dB { O 43 X 30 Δ 24 }

However, such a conclusion may be misleading, because even if the visibility of the interference as a separate coherent pattern is reduced by the addition of random noise, the total impairment of the picture may be increased. In order to check this effect, six observers graded the total impairment with random noise and interference combined in various proportions. The range of unweighted s.n.r.s presented was from 31 to 43 dB, and the range of protection ratios from 43 to 57 dB. A few more tests of a similar nature were later carried out by members of a Working Group, as for the tests in Section 7. The results of the tests are shown in Fig. 8, and they confirm that the total picture impairment tends to increase when interference and noise are added. The number of tests was too small to enable a precise "law of addition" to be deduced,
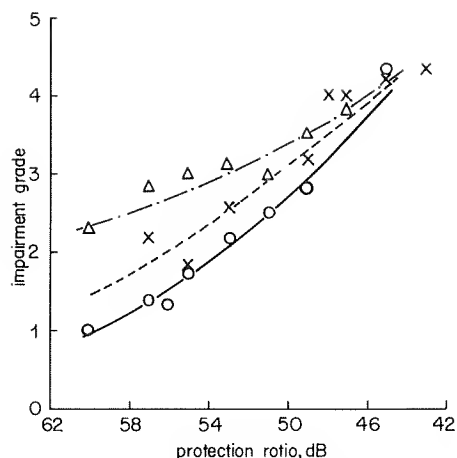
Fig. 8 - Effect of combined noise and interference

system s.n.r. (unweighted), dB

—○— >39 dB
---✕--- 35 – 39 dB (inc.)
---△--- <35 dB

but the results shown in Fig. 8 indicate that if a given impairment grade is to be maintained, the p.r. may have to be increased, rather than decreased, if random noise is also to be taken into account.

11. Effect of energy-dispersal waveform

Energy-dispersal waveforms, added to the video modulating signal, reduce the effects of interference on f.m. multi-channel telephony systems, but they are less effective in the case of f.m. television interfering with f.m. television. It may, however, be expected that a benefit is obtained in the present case of f.m. interfering with a.m. television, particularly when the interfering modulation is at a constant level, such as black. To check this assumption, a 50 Hz sinewave was added to the modulating input of the interfering f.m., and its effect on the p.r. was assessed. Three different levels of this energy-dispersal signal were used, corresponding to peak-to-peak deviations of 0·4, 0·8 and 1·6 MHz. The peak-to-peak deviation of the picture modulation was maintained at a nominal 8 MHz without the addition of the energy-dispersal waveform, and pre-emphasis was included. The interfering modulation was either colour bars or black level with syncs. The p.r. was first set to give an impairment of about grade 3, with no energy-dispersal included. The energy-dispersal was then added, and the p.r. re-adjusted to maintain the same degree of impairment. The assessments of one fairly experienced observer are given in Table 1.

TABLE 1

Effect of energy-dispersal waveform

Peak-to-peak deviation of energy-dispersal waveform, MHz		0	0·4	0·8	1·6
Protection ratio, dB	Interfering colour bars	49	48	48	47
	Interfering black level	54	53	52	49

As may be expected, the benefit obtained when the interference is fully modulated is relatively small (up to 2 dB), but for black level interference, which requires considerably more protection without dispersal, there is an improvement of 5 dB when the peak-to-peak deviation of the energy-dispersal waveform is 1·6 MHz.

12. Conclusions

If the acceptable impairment is taken as grade 1·5, the protection ratio when the signal-to-noise ratio of the wanted picture is high should be about 56 dB, if the peak-to-peak deviation of the interference is taken as 8 MHz. This recommendation represents a more stringent requirement than that previously quoted. This may be partly because it is based on the use of a fairly sensitive still picture for the wanted signal. However, a picture of the type used may often occur in the practical situation.

A somewhat lower protection ratio may be acceptable at the fringe of the terrestrial service area. Annex 3-4A to the CCIR Report of the Special Joint Meeting, Geneva 1971, suggests that a good installation in such an area can provide a picture with an s.n.r. (unweighted) of 36 to 37 dB, if there is no noise in the transmitted picture. Since future technical developments should reduce the source noise to relatively small values, the total s.n.r. will be governed by the receiving installation. Fig. 8 shows that, for a picture with a 37 dB s.n.r., the introduction of an f.m. interfering signal at 53 dB below the wanted signal would increase the total impairment grade from about 2 to 2·5. This suggests that 53 dB may be a reasonable protection ratio in the fringe area.

Some reduction in the protection ratio may be permitted if a larger peak-to-peak deviation is employed for the f.m. signal, and if an energy-dispersal waveform is added to the modulation of the f.m., as discussed in Sections 8 and 11.

13. References

1. CCIR Report of Special Joint Meeting, 1971, Section 3.4.1.

2. CCIR Recommendation No. 418-2, New Delhi 1970, Vol. V.

3. Satellite broadcasting: co-channel protection ratios for f.m. television. BBC Research Department Report No. 1971/19.

4. Subjectively measured interference between a frequency-modulation television signal and an amplitude-modulation vestigial-sideband television signal. CCIR Document M/55-E, November 1970.

5. Subjectively measured interference on amplitude-modulation and frequency-modulation colour television signals. CCIR Document M/76-E, November 1970.

6. CCIR XIIth Plenary Assembly, New Delhi 1970, Vol. IV, Part I, Recommendation 405-1, p. 150, curve B.